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(54) NON-RECIPROCAL CIRCUIT ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To reduce the insertion loss and obtain excellent temperature stability in frequency, by constituting the ratio of saturation magnetization of a permanent magnet and that of microwave ferrite to be greater than the ratio at the time of normal temperature, on both low and high temperature sides.

SOLUTION: The ratio (Msm/Msf) of saturation magnetization (Msm) of a permanent magnet and saturation magnetization (Msf) of microwave ferrite is set to be greater than the ratio at the time of normal temperature, on both low and high temperature sides. Temperature coefficient of the microwave ferrite is set to be −0.27 to −0.34%/° C on the high temperature side (60-100° C), and 0 to 0.18%/° C on the low temperature side (−40 to 20° C). The mean value of temperature coefficient of saturation magnetization (Msf) of a garnet type ferrite is set to be 0 to −0.18%/° C in the temperature region of −40 to 20° C, and −0.27 to −0.34%/° C in the temperature region of 60 to 100° C.
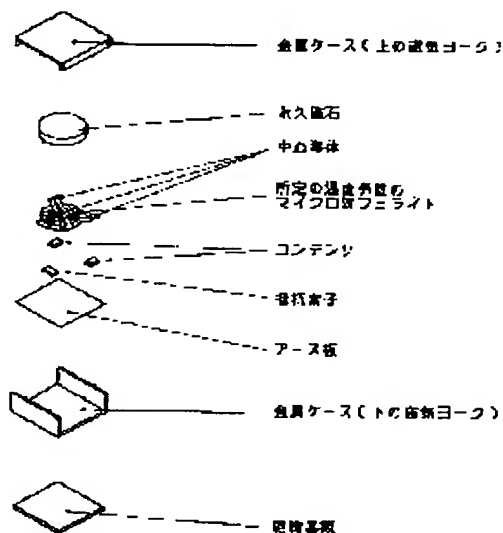
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CLAIMS

[Claim(s)]
[Claim 1] The non-reciprocal circuit element which is a non-reciprocal circuit element which
operates by the magnetic field higher than a ferromagnetic-resonance magnetic field, and is
characterized by the value of the ratio (Msm/Msf) of the saturation magnetization (Msm) of a
permanent magnet and the saturation magnetization (Msf) of a microwave ferrite being size from
the time of ordinary temperature also in any by the side of low temperature and an elevated
temperature.
[Claim 2] Permanent magnet. The principal component which is a magnetic yoke is an iron metal
case. The microwave ferrite to which the magnetic flux of this permanent magnet is impressed.
Two or more striplines arranged near [a microwave ferrite] this. The capacity element
electrically connected to this stripline. It is the non-reciprocal circuit element equipped with the
above. the temperature coefficient of the saturation magnetization (Msf) of the aforementioned
microwave ferrite - Average in 40 Degrees C - 20 Degrees C Temperature Field is 0%/Degree-
C-Alpha%/** (however, Temperature Coefficient [in / -40 Degrees C - 20 Degrees C of
Saturation Magnetization (Msm) of the Aforementioned Permanent Magnet / in Alpha]). And it is
characterized by the average in a 60 degrees C - 100 degrees C temperature field being %
(1.5xbeta)/**-(1.9xbeta) %/** (however, temperature coefficient [in / 60 degrees C - 100
degrees C of the saturation magnetization (Msm) of the aforementioned permanent magnet / in
beta]).
[Claim 3] Permanent magnet. The principal component which is a magnetic yoke is an iron metal
case. The garnet ferrite to which the magnetic flux of this permanent magnet is impressed. Two
or more striplines arranged near [garnet ferrite] this. The capacity element electrically
connected to this stripline. It is characterized by the average in the temperature field to which
the average [in / a -40 degrees C - 20 degrees C temperature field / it is the non-reciprocal
circuit element equipped with the above, and the aforementioned permanent magnet is a ferrite
magnet, and / in the temperature coefficient of the saturation magnetization (Msf) of the
aforementioned garnet ferrite] is 0% //degree C / - -0.18%/degree C, and is 60 degrees C - 100
degrees C being -0.27% //degree C / - -0.34%/degree C.
[Claim 4] Empirical formula GdzY Magnetic material characterized by the bird clapper from the
composition with which it is expressed with 3-2 x-zCa2xFe2-ylnyFe3-xVxO12, and is satisfied of
0< x<=0.7, 0.25< y<=0.4, and 0.35<=z<=1.6 in the aforementioned empirical formula.
[Claim 5] How to compensate the temperature characteristic of the non-reciprocal circuit
element which is the method of compensating the temperature characteristic of a non-reciprocal
circuit element which operates by the magnetic field higher than a ferromagnetic-resonance
magnetic field, and is characterized by making it the value of the ratio (Msm/Msf) of the
saturation magnetization (Msm) of a permanent magnet and the saturation magnetization (Msf) of
a microwave ferrite serve as size from the time of ordinary temperature also in any by the side
of low temperature and an elevated temperature.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] this invention relates to the method of the temperature compensation for obtaining a non-reciprocal circuit element of having excelled in the temperature characteristic of an insertion loss or center frequency or, about the magnetic material for obtaining the non-reciprocal circuit element which was excellent in the temperature characteristic about a circulator, concentrated-constant type the non-reciprocal circuit element, i.e., the isolator, used below 100MHz or more 20GHz.
[0002]
[Description of the Prior Art] Non-reciprocal circuit elements, such as an isolator and a circulator, are used for the RF device which used the 20GHz frequency band from 100MHz in many cases. This element makes the RF of the forward direction pass with low loss on specific frequency, and has the function to make the RF of an opposite direction prevent.
[0003] The usual concentrated-constant type non-reciprocal circuit element is the structure where a permanent magnet and the principal component which is the magnetic yoke have an iron metal case, the microwave ferrite to which the magnetic flux of a permanent magnet is impressed, two or more striplines and central conductor which have been arranged near [this] the microwave ferrite, and the capacity element (for example, capacitative element like a chip capacitor) electrically connected to this stripline. Moreover, usually, the above-mentioned microwave ferrite and the above-mentioned magnet are arranged so that it may be piled up.
[0004] In addition, if termination of the one terminal of 3 terminal circulator which is one of the non-reciprocal circuit elements is carried out by the resistance element, it becomes an isolator, and as for an isolator and a circulator, the gestalt top is also technically similar.
[0005] There is loss at the time of passage of the RF which makes one of the most important properties required of this non-reciprocal circuit element pass the element concerned to the forward direction, i.e., an insertion loss. Needless to say, an insertion loss is so good that it is small. In order to maintain the performance excellent in the temperature requirement with the above-mentioned still larger non-reciprocal circuit element, the temperature characteristic of an insertion loss also needs to be excellent.
[0006] On the other hand, the frequency characteristic is in other one of the most important properties required of a non-reciprocal circuit element. A non-reciprocal circuit element uses a ferromagnetic resonance, and is usually designed by the view of ABABU resonance (the design method with which it is made resonant [by the high magnetic field side] from the direct-current magnetic field from which mu+" of an avobe resonanse; microwave ferrite becomes the maximum).
[0007] Frequency is set up so that it may become the operating frequency of the non-reciprocal circuit element concerned. That is, it is set up so that the frequency determined in approximation by the size of the saturation magnetization (it is hereafter described as Msf) of a microwave ferrite, the sizes of the saturation magnetization (it is hereafter described as Msm) of a permanent magnet, and those ratios may turn into operating frequency.
[0008] In order to maintain the performance excellent in the temperature requirement with a

large non-reciprocal circuit element, even if environmental temperature changes, it is important to cope with it so that a frequency of operation may seldom be changed.

[0009] From this viewpoint, it divided roughly into the temperature compensation of the conventional non-reciprocal circuit element, and there was the method of two kinds of a cure and management in it. That is, the 1st method is making it each temperature coefficient of Msf and Msm become small.

[0010] For example, it is the method of adopting the permanent magnet of the high metal system of Curie temperature, for example, a rare earth permanent magnet, in order to lessen change of Msm, adjusting the magnetic reluctance of a direct-current magnetic circuit combining magnetic shunt steel further, and performing more exact temperature compensation at the same time it adopts the microwave ferrite of a Gd substitution type YIG system and the change to the temperature of Msf chooses the material of few composition, in order to make Msf small.

[0011] The cure by such method is shown in for example, the Provisional-Publication-No. 50 No. 31400 official report per year, or the Provisional-Publication-No. 57 No. 42544 official report per year. When based on this method, a permanent magnet expensive naturally and expensive magnetic shunt steel will be used.

[0012] Then, what it was considered whether could use a ferrite magnet as a cheaper permanent magnet is the 2nd method. Since Curie temperature is lower than a metal system magnet, a ferrite magnet cannot be said for the temperature coefficient of Msm to be not necessarily small with being known well. However, if the temperature coefficient of Msf and the temperature coefficient of Msm are sizes of the same grade, even if environmental temperature will change, the frequency of operation has been prevented from changing not much.

[0013] Therefore, choosing and combining a microwave ferrite and the material of a ferrite magnet so that the temperature coefficient of Msf and the temperature coefficient of Msm may serve as a size of the same grade was performed. if this puts in another way -- the ratio of the size of the saturation magnetization (Msf) of a microwave ferrite, and the generating magnetic field strength of a permanent magnet -- always -- fixed -- making .

[0014] However, even if it was the non-reciprocal circuit element which must fully have carried out temperature compensation by the 2nd method of the above, when the insertion loss of the element and the temperature characteristic of center frequency were seen, it tended to become a value inadequate except an ordinary temperature region.

[0015] That is, it was not easy to offer the non-reciprocal circuit element which always had few insertion losses and was excellent in the temperature stability of a frequency of operation to change of environmental temperature.

[0016]
[Problem(s) to be Solved by the Invention] Then, the technical problem which this invention tends to solve is at least one of the technical problems enumerated below.

(1) the temperature field where the offer (2) frequency of operation of the non-reciprocal circuit element the insertion loss continued and excelled [element] in the large temperature field is large -- continuing -- offer (3) of a stable non-reciprocal circuit element -- a large temperature field -- continuing -- a temperature field large excellent [an insertion loss] -- continuing -- offer (4) of a non-reciprocal circuit element with a stable frequency of operation -- offer of a magnetic material to which it is cheap and the highly reliable offer (5) above-mentioned technical problem of a non-reciprocal circuit element solves any one

(6) Offer of the compensation method of the temperature characteristic that the above-mentioned technical problem solves any one easily at least.

[0017]
[Means for Solving the Problem] In order to solve an above-mentioned technical problem, this invention persons hit on an idea wholeheartedly to the new method of compensating the magnetic material for obtaining the non-reciprocal circuit element which has improved composition remarkably, or this non-reciprocal circuit element, or the temperature characteristic of this non-reciprocal circuit element as a result of research.

[0018] That is, the 1st invention is a non-reciprocal circuit element which operates by the magnetic field higher than a ferromagnetic-resonance magnetic field, and is the non-reciprocal

circuit element which the value of the ratio (Msm/Msf) of the saturation magnetization (Msm) of a permanent magnet and the saturation magnetization (Msf) of a microwave ferrite constituted also in any by the side of low temperature and an elevated temperature so that it might become size from the time of ordinary temperature.

[0019] The greatest feature of this invention is in the place where supposing that it is conventionally fixed made the value of Msm/Msf considered to be the best larger than the value in ordinary temperature not only at a low temperature side but at the elevated-temperature side. Even if it makes only the value of Msm/Msf near ordinary temperature small, it is the same as a result.

[0020] By considering as such composition, low loss and a thing non-reciprocal circuit element with little frequency-of-operation change are obtained by the large temperature requirement. That is, since it leads to the fast improvement in the guarantee specification of the non-reciprocal circuit element concerned, the place which contributes is size very much.

[0021] In addition, although it is needless to say, since the non-reciprocal circuit element completed as parts is the thing of one, it cannot take the separate part composition which was suitable for each in three sorts of temperature zone regions near ordinary temperature a low temperature and elevated-temperature side.

[0022] The following facts are considered to involve intricately although it is not necessarily theoretically clear about the reason composition like the 1st invention also by artificers' examination result is effective.

[0023] The permeance of a magnetic circuit should change with the temperature characteristics and coefficient of thermal expansion of permeability of the MAG yoke made from Fe. For the size of the imaginary part (usually described as mu+") which generally expresses loss of the permeability to the clockwise circularly-polarized wave of tensor permeability, the more impression magnetic field strength separates from the magnetic field which starts a ferromagnetic resonance, the more this is a bird clapper small. Loss in the permanent magnet of the microwave revealed or spread in a permanent magnet should change with environmental temperature.

[0024] Setting to this invention, for ordinary temperature, a temperature [of about 20 degrees C] and low temperature side is [about]. -40-degree-C or more temperature [of 10 degrees C or less] and elevated-temperature side is 100 degrees C or less in about 40-degree-C or more temperature.

[0025] This application the 2nd invention considers the content of the 1st invention of a **** as still more concrete composition. A permanent magnet and the principal component which is a magnetic yoke the 2nd invention Namely, an iron metal case, The microwave ferrite to which the magnetic flux of this permanent magnet is impressed, and two or more striplines arranged near [a microwave ferrite] this, It is the non-reciprocal circuit element which has the capacity element electrically connected to this stripline. the temperature coefficient of the saturation magnetization (Msf) of the aforementioned microwave ferrite - Average in 40 Degrees C - 20 Degrees C Temperature Field is 0%/Degree-C-Alpha%/** (however, Temperature Coefficient [in / -40 Degrees C - 20 Degrees C of Saturation Magnetization (Msm) of the Aforementioned Permanent Magnet / in Alpha]). And it is the non-reciprocal circuit element constituted so that the average in a 60 degrees C - 100 degrees C temperature field might be %(1.5xbeta)/**-(1.9xbeta) %/** (however, temperature coefficient [in / 60 degrees C - 100 degrees C of the saturation magnetization (Msm) of the aforementioned permanent magnet / in beta]).

[0026] In this invention, it is "permanent magnet and - non-reciprocal circuit element of the beginning, and the portion of " is the general composition of the conventional concentrated-constant type non-reciprocal circuit element. Therefore, this portion may be composition besides analogous. A stripline is a central conductor and, in the case of 3 terminal circulator or 3 terminal isolator, it consists of three.

[0027] Although a capacity element is a capacitor in short, the latest thing has many tipped types and things of ceramic substrate combination. The function usually has the function of impedance matching, and a function as a microwave filter.

[0028] Moreover, the average [in / a -40 degrees C - 20 degrees C field / in the temperature

coefficient of saturation magnetization] is given by x(/(Ms20-Ms-40) Ms 20/60) 100, and the average in a 60 degrees C - 100 degrees C field is similarly given by x(/(Ms100-Ms60) Ms 20/40) 100 (a unit is %/**.). Each number with the lower right of Ms shows temperature, for example, Ms-40 show the saturation magnetization in -40 degrees C. 60 in a formula and 40 are the temperature width of face (unit **) of the temperature field concerned. It is a thing. The value of these saturation magnetization and the temperature characteristic of saturation magnetization can be easily measured correctly with an oscillating sample type magnetometer (VSM).

[0029] If this is expressed to one drawing when this invention is expressed from another viewpoint, and each temperature characteristic of Msf of a permanent magnet and a microwave ferrite is standardized with the value in those 20 degrees C, respectively, those temperature characteristic lines mean a bird clapper in the relation of two curves which touch mutually near ordinary temperature and have the temperature characteristic line of a microwave ferrite inside it of a permanent magnet.

[0030] If the concrete inclination of the temperature characteristic is shown about the case where made the permanent magnet of invention of the above 2nd into the ferrite magnet, and a microwave ferrite is made into a garnet ferrite, it will become this application the 3rd invention.

[0031] A permanent magnet and the principal component which is a magnetic yoke this application the 3rd invention Namely, an iron metal case, The garnet ferrite to which the magnetic flux of this permanent magnet is impressed, and two or more central conductors arranged near [garnet ferrite] this, It is the non-reciprocal circuit element which has the capacitative element electrically connected to this central conductor. The aforementioned permanent magnet is a ferrite magnet, and the average [in / a -40 degrees C - 20 degrees C temperature field / in the temperature coefficient of the saturation magnetization (Msf) of the aforementioned garnet ferrite] is 0% //degree C / - -0.18%/degree C. And it is the non-reciprocal circuit element constituted so that the average in a 60 degrees C - 100 degrees C temperature field might be -0.27% [/degree C] - -0.34%/degree C.

[0032] In this invention, if a ferrite magnet is Sr ferrite, in addition, it is good. Compared with a metal magnet, specific resistance of a ferrite magnet is large, and it is effective in lessening loss by the high frequency band. If this is furthermore Sr ferrite magnet, compared with Ba ferrite, the linearity of the temperature characteristic of Msm is excellent, and a temperature coefficient is [about]. -While being 0.18%/degree C, it is usable at a latus temperature requirement.

[0033] Moreover, if a garnet ferrite is Gd-calcium-V-In substitution type YIG, in addition, it is good. **H (resonance absorption half-value width) related to loss of a garnet is small -- in addition, it is because the application range spreads since the material of the temperature coefficient specified to this paragraph can create easily and the setting range of the realization possibility of, i.e., a frequency of operation, becomes large about various values of Msf of ordinary temperature

[0034] However, it is fully possible to realize the temperature coefficient specified to this paragraph also by Gd substitution type garnet, although the value of Msf of ordinary temperature has restrictions a little. It cannot be overemphasized that you may be the garnet of other systems.

[0035] Although invented based on this knowledge, one is the garnet ferrite of Gd-calcium-V-In substitution type YIG of invention of this application 4th. That is, this application the 4th invention is a magnetic material which is expressed with empirical-formula GdzY3-2 x-zCa2xFe2-yInyFe3-xVxO12, and satisfies 0< x<=0.7, 0.25< y<=0.4, and 0.35<=z<=2.0.

[0036] If this magnetic material is applied to this application 1-3rd invention, the non-reciprocal circuit element excellent in the temperature characteristic of an insertion loss or a frequency of operation will be obtained.

[0037] For this application the 5th invention, a technical content is common in the 1st invention about a method. That is, this application the 5th invention is the method of compensating the temperature characteristic of a non-reciprocal circuit element which operates by the magnetic field higher than a ferromagnetic-resonance magnetic field, and the value of the ratio (Msm/Msf) of the saturation magnetization (Msm) of a permanent magnet and the saturation magnetization (Msf) of a microwave ferrite is the method of compensating the temperature characteristic of

the non-reciprocal circuit element it is made to serve as size from the time of ordinary temperature also in any by the side of low temperature and an elevated temperature.

[0038]

[Embodiments of the Invention] Drawing 1 is the decomposition perspective diagram of an isolator in this case of the typical non-reciprocal circuit element for explaining this invention. Since drawing 1 is typically drawn in order to secure visibility, it is not exact about a scale or configuration of each part.

[0039] The outline about the portion which is common for the concentrated-constant type non-reciprocal circuit element of a conventional type among the structures of a non-reciprocal circuit element first is as follows when for example, the object for mobile communications is explained to an example based on drawing 1 . However, it cannot be overemphasized that you may be various isolators and circulators other than the type of drawing 1 .

[0040] The magnetic yoke under iron is fixed to the insulating substrate which has an external terminal electrode, a copper grounded plate (an ellipsis is possible) is soldered to this, the grounding section of a central conductor is soldered on it, and a disc-like microwave ferrite is fixed on it (for example, heating adhesion is carried out by the resin), and one terminal of the stripline section of the above-mentioned central conductor is bent so that the above-mentioned microwave ferrite may be wrapped. Then, other one terminal of the above-mentioned central conductor is bent similarly, and an insulating film (not shown) is inserted between previous terminals. The terminal which repeated the same procedure and remained is inserted in.

[0041] What fixed the disc-like permanent magnet to the magnetic yoke after preparing beforehand, magnetized the (for example, the method of carrying out heating adhesion by the resin may be used) permanent magnet to this with the direct-current electromagnet, and adjusted magnetism to it is inserted in.

[0042] Moreover, the extension section from the stripline section of the above-mentioned central conductor is made to connect to the I/O external terminal prepared in the above-mentioned insulating substrate. Furthermore between the extension section from the stripline section of the above-mentioned central conductor, and the above-mentioned grounded plate, the chip capacitor for adjustment is inserted, and it connects. It replaces with a chip capacitor and there is also a method using the dielectric substrate of a ceramic.

[0043] Thus, by tuning the generating magnetism of the above-mentioned permanent magnet finely, the created non-reciprocal circuit element is correctly set up so that it may become a desired frequency of operation.

[0044] In addition, the number of the above-mentioned input/output terminals is three here, and one of pieces of it can create arrangement which is connected to a grounded plate through a resistance element, then the isolator which makes two pieces which remained an input terminal and an output terminal.

[0045] Next, the outline is explained about the gestalt of operation of the invention in this application. What is necessary is to measure an above-mentioned permanent magnet, the saturation magnetization (Msm) of a microwave ferrite, and the temperature characteristic of (Msf), respectively, to compare in quest of the temperature coefficient of those predetermined temperature fields, to select the thing in the predetermined range, and just to consider as a non-reciprocal circuit element using the material chosen as a result of the selection.

[0046] Or what is necessary is to adopt Sr ferrite magnet for a ferrite magnet still more desirably especially, to adopt a garnet ferrite and the garnet-ferrite material which has still more desirable predetermined composition especially as a microwave ferrite as a permanent magnet, and just to consider as a non-reciprocal circuit element using these.

[0047] The detail of the invention in this application is explained based on an example below.

[Example] (Example 1) An example 1 is related with the experiment which performed each temperature coefficient of the saturation magnetization of various Gd-calcium-V-In substitution type YIG, and the relation with the insertion loss of a non-reciprocal circuit element and the temperature characteristic of a frequency of operation which were created using them as an anisotropy Sr ferrite magnet and a microwave ferrite as a permanent magnet to the well to clarify.

[0048] The commercial anisotropy Sr ferrite-magnet disk was prepared first. The temperature characteristic of the saturation magnetization (Msm) was measured using VSM. Furthermore as a microwave ferrite, the material of the various amounts of substitution of Gd-calcium-V-In substitution type YIG was created, and what was processed into disc-like was prepared. The temperature characteristic of these saturation magnetization (Msf) was also measured using VSM.

[0049] The creation procedure of the above-mentioned Gd-calcium-V-In substitution type YIG is as follows. All prepared the powder of Gd2O3 of a special grade chemical, CaCO3, V2O5, In2O3, Y2O3, and Fe2O3 in commercial elegance.

[0050] Furthermore, after carrying out weighing capacity of the powder prepared above and mixing in ethyl alcohol for 24 hours using a ball mill so that it may become the composition which carried out zero to 0.7, and y by zero to 0.6, and z made carry out various change of x of empirical-formula GdzY3-2 x-zCa2xFe2-yInyFe3-xVxO12, and y and z within the limits of 0-2, x was dried and cracked and obtained mixed powder, respectively.

[0051] In the case made from a ceramic, temporary quenching of these mixed powder was carried out in 2 hours and 1000-degree-C air atmosphere, and it was taken as temporary-quenching powder. This temporary-quenching powder was ground in ethyl alcohol for 24 hours using the ball mill after a crack. The considerable amount was added 1% of the weight, it corned, and polyvinyl alcohol solution of 10% of concentration is made into a solid content, and raw material granulatio took [the particle size regulation was carried out and] after drying this.

[0052] Metal mold was filled up with the raw material granulatio which carried out [above-mentioned] creation, and the Plastic solid disc-like by about 100 MPa(s) was obtained by the dry type compression moulding technique by the hydraulic press. These Plastic solids were calcinated in 1270-degree-C oxygen atmosphere for 3 hours, and were taken as the baking object. These baking objects gave polish processing to the periphery and the vertical side, and made it the microwave ferrite for non-reciprocal circuit elements.

[0053] In addition, when these baking objects were separately checked with the X-ray diffraction method, they were garnet single phase mostly. as other basic properties -- Msf in ordinary temperature -- 50-130mT -- it is -- moreover, ferromagnetic-resonance half-value-width **H -- the thing of 560 - 6,900 A/m (however, most samples within the limits of 1,800 - 2,100 A/m) -- various profit ****

[0054] The temperature characteristic of an insertion loss was measured about what was adjusted so that might combine the permanent magnet prepared above and various microwave ferrites, a non-reciprocal circuit element might be created in the usual way, and an insertion loss might serve as the minimum in the ordinary temperature of 20 degrees C and a frequency of operation might be set to about 300MHz. A measuring instrument and system of measurement are based on the their original work fixture which serves as a thermostat and a network analyzer from the cable adjusted correctly and an end-connection child.

[0055] In addition, the insertion loss of a non-reciprocal circuit element and the point of measurement of a frequency of operation could be -10 degrees C, 20 degrees C, and 80 degrees C. - 10 degrees C is [ordinary temperature and 80 degrees C of the temperature of a -40 degrees C - 20 degrees C midpoint and 20 degrees C] the temperature of a 60 degrees C - 100 degrees C midpoint.

[0056] Moreover, 300MHz of frequency is because the low frequency is more advantageous in order to make a judgment exact although it belongs to a low frequency band most, considering a use. It checked by about 2GHz separately, and the justification of the judgment has been checked. That is, at least 2GHz is a book.

[0057] The result measured as mentioned above is shown in drawing 2 . Drawing 2 is the value of the 80-degree C insertion loss of each isolator created using the temperature coefficients (however, average of 60 degrees C - 100 degrees C) and these microwave ferrites of saturation magnetization (Msf) of various microwave ferrites, and each permanent magnet used at this time is Sr ferrite (the average of 60 degrees C - 100 degrees C of a temperature coefficient is 0.19%/degree C).

[0058] According to drawing 2 , if the value of an insertion loss has the temperature coefficient

(however, average of 60 degrees C - 100 degrees C) of the saturation magnetization (Msf) of a microwave ferrite within the limits of -0.27--0.34, it is very small, namely, has become 0.2dB or less.

[0059] Furthermore, when the above-mentioned temperature coefficient is near 0%/degree C, and when the above-mentioned temperature coefficient is near -0.19%/degree C, an insertion loss is 0.25dB or more, although what should be observed is not a bad value, I hear that it cannot say either of the cases as the best, and it has them.

[0060] The examination result by the side of the low temperature measured similarly is shown in drawing 3 . Drawing 3 is the temperature coefficient (however, average of -40 degrees C - 20 degrees C) of the saturation magnetization (Msf) of various microwave ferrites, and the value of the -10-degree C insertion loss of each isolator created using these microwave ferrites, and the -40 degrees C - 20 degrees C average of the temperature coefficient of the permanent magnet Sr ferrite used at this time is 0.18%/degree C.

[0061] If the value of the insertion loss [according to drawing 3] in -10 degrees C is in within the limits whose temperature coefficient (however, average of -40 degrees C - 20 degrees C) of the saturation magnetization (Msf) of a microwave ferrite is 0--0.18%/degree C, it is very small, namely, has become 0.2dB or less.

[0062] What should be observed further here is having the optimum point in the position where the above-mentioned temperature coefficient's differs from the optimum point in a previous temperature coefficient (60-100 degrees C). When the case of 0%/degree C or more and the above-mentioned temperature coefficient are -0.19%/degree C or less, it is 0.2dB or more, and although an insertion loss is not a bad value, it can say neither of the cases as the best.

[0063] Drawing 4 and drawing 5 are as a result of [which made the place of an insertion loss the variation of a frequency of operation under the same conditions as the examination in drawing 2 and drawing 3] evaluation. It is shown that the frequency of operation low-frequency-ized the negative sign. the temperature coefficient (average of 60 degrees C - 100 degrees C) of Msf from which the variation of the frequency of operation in 80 degrees C on the basis of 20 degrees C is set to less than 5MHz according to drawing 4 -- about -- it is -0.23--0.36%/degree C

[0064] Moreover, the temperature coefficient (average of -40 degrees C - 20 degrees C) of Msf from which the variation of the frequency of operation in -10 degrees C on the basis of 20 degrees C is set to less than 5MHz according to drawing 5 is [about]. -It is 0.4 - +0.02%/degree C.

[0065] Even if the point which should be noted from drawing 4 and the fact shown in 5 makes in agreement simply the temperature coefficient of a permanent magnet, and the temperature coefficient of a microwave ferrite, an ideal temperature compensation is compensating so that the saturation magnetization of a ferrite may become less than the point which was an established theory conventionally more in a difficult thing, especially low temperature side.

[0066] When drawing 2 - drawing 5 are furthermore judged synthetically, the temperature coefficient of the microwave ferrite for obtaining a non-reciprocal circuit [with few / and / insertion losses] element with little variation of a frequency of operation is 0 - 0.18%/degree C at an elevated-temperature side (60-100 degrees C) in a -0.27--0.34%/degree-C and low temperature side (-40-20 degrees C).

[0067] (Example 2) Next, it investigated in detail about the relation between each value of x, and y and z which is the atomic ratio of each element component of Gd-calcium-V-In substitution type YIG which is the garnet type microwave ferrite used in the example 1, and the above-mentioned temperature coefficient. The result is shown below.

[0068] What is necessary is just to perform it as follows, in order to make it the average in the temperature field which the average [in / a -40 degrees C - 20 degrees C temperature field / for the temperature coefficient of the saturation magnetization (Msf) of Gd-calcium-V-In substitution type YIG] is 0% //degree C / - -0.18%/degree C, and is 60 degrees C - 100 degrees C become degree C in -0.27% //degree C / - -0.34% /.

[0069] Namely, empirical-formula $Gd_zY_{3-2 x-z}Ca_{2x}Fe_{2-y}In_yFe_{3-x}V_xO_{12}$ What is necessary is just to consider as $0< x<=0.7$, $0.25< y<=0.4$, and the composition with which are satisfied of

0.35<=z<=1.6.

[0070] However, although above-mentioned conditions will be fulfilled if it says only within a temperature coefficient even if it is x> 0.7 and z< 0.35, sintering progresses superfluously in this case and it does not become the material of low loss. Moreover, in y<=0.25, since crystal grain becomes detailed, it does not become low loss. In y>=0.4, the temperature coefficient by the side of low temperature serves as negative, it is not suitable, sintering progresses superfluously, and loss is worsened. The temperature coefficient by the side of low temperature becomes excessive [the temperature coefficient by the side of an elevated temperature] at excess and z> 1.6, and is not desirable at z< 0.35.

[0071] For example, **** when being referred to as empirical-formula Gd0.8Y1.2calcium1Fe1.7In0.3Fe2.5V0.5O12, x= 0.5 [i.e.,], y= 0.3, and z= 0.8 became as follows. About the microwave ferrite, 20-degree C saturation magnetization (Msf) was 75mT(s), and ferromagnetic-resonance-absorption half-value width (**H) was 1240 A/m. The temperature coefficient was -0.29%/degree C by -40 degrees C - 20 degrees C at -0.17% /and 60 degrees C - 100 degrees C degree C in -0.15% /and about 20 degrees C degree C.

[0072] About the non-reciprocal circuit element created using this microwave ferrite, the insertion loss was 0.18dB at 0.17dB and 80 degrees C in 0.19dB and 20 degrees C by -10 degrees C, and the frequency of operation was 330MHz at 329MHz and 80 degrees C in 330MHz and 20 degrees C by -10 degrees C.

[0073] (Example 3) Both the anisotropy Ba ferrite magnet the isotropic samarium cobalt system magnet and the isotropic Nd-Fe-B system magnet changed the place of Sr ferrite magnet of an example 1 to commercial elegance, and the same examination as an example 1 was performed. However, about the isotropic samarium cobalt system magnet and the isotropic Nd-Fe-B system magnet, it considered as disc-like [thinner than a ferrite magnet] for frequency-of-operation adjustment.

[0074] When the temperature characteristic of the saturation magnetization (Msm) of each magnet was measured using VSM, change of the temperature coefficient by temperature had little any material, and the anisotropy Ba ferrite magnet was [-0.04%/degree C and the isotropic Nd-Fe-B system magnet of -0.19%/degree C and the isotropic samarium cobalt system magnet] -0.12%/degree C.

[0075] When asked for the optimal temperature coefficient of a microwave ferrite like the example 1, about the anisotropy Ba ferrite magnet, the almost same result as an example 1 was obtained. About the isotropic samarium cobalt system magnet, -0.6--0.8%/degree C was the optimal in the low temperature side (-40-20 degrees C) at the 0--0.4%/degree-C and elevated-temperature side (60-100 degrees C). About the isotropic Nd-Fe-B system magnet, -0.17--0.23%/degree C was the optimal in the low temperature side at the 0--0.12%/degree-C and elevated-temperature side.

[0076] According to the above result, the optimal range of the temperature coefficient of the microwave ferrite for non-reciprocal circuit elements is decided by the ratio with the temperature coefficient of a permanent magnet. - As for 40 degrees C - 20 degree-C temperature coefficient, 0-alpha%/** and 60 degrees C - 100 degree-C temperature coefficient were found by that %(1.5xbeta)/** - (1.9xbeta) %/** is an optimum (however, temperature coefficient [in / this temperature region of the saturation magnetization (Msm) of a permanent magnet / in alpha and beta]).

[0077] (Example 4) It checked like [case / where both Gd substitution type YIG and an aluminum substitution Co dope type nickel system spinel ferrite change the place of Gd-calcium-V-In substitution type YIG of an example 3 to the commercial elegance of the various amounts of substitution about the relation of the optimum-temperature coefficient made clear in the example 3] the example 3. Consequently, the above and this conclusion were obtained.

[0078] Furthermore, in order to change a setup of a frequency of operation, when the saturation magnetization (Msf) of strength and a microwave ferrite chose the material of larger composition and made the impression magnetic field to a microwave ferrite as an experiment, it checked that at least 2GHz did not have change in the above-mentioned conclusion.

[0079] In addition, the structure of a non-reciprocal circuit element shall differ from the

structure shown in <u>drawing 1</u> the following point in this trial production. a lower magnetic yoke ─── abbreviation ── it presupposed that it is monotonous, and the upper magnetic yoke was made into the enclosed type which has a pore, it prepared the pin terminal in the pore and made it the input/output terminal The insulating substrate omitted. The capacity of a capacitor and the power-proof nature of a resistance element were changed.

[0080]

[Effect of the Invention] As explained to the detail above, according to this invention, it became possible to offer the non-reciprocal circuit element which made it low loss and was excellent in the temperature characteristic of loss or a frequency of operation. Or offer of the microwave ferrite for these non-reciprocal circuit elements was attained. Or it was able to be made ideal and the new temperature-compensation method was able to be offered.

[Translation done.]

* NOTICES *

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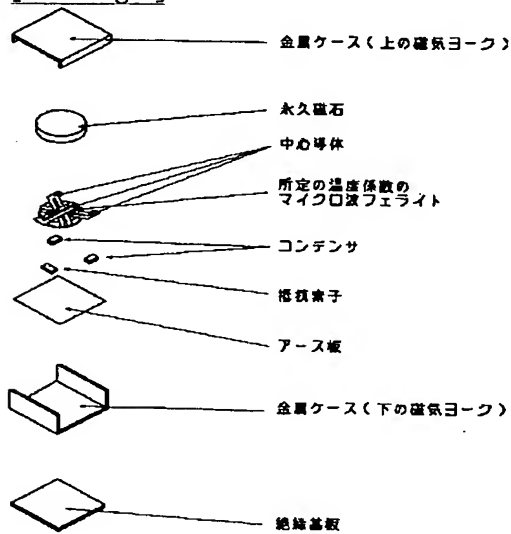damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.
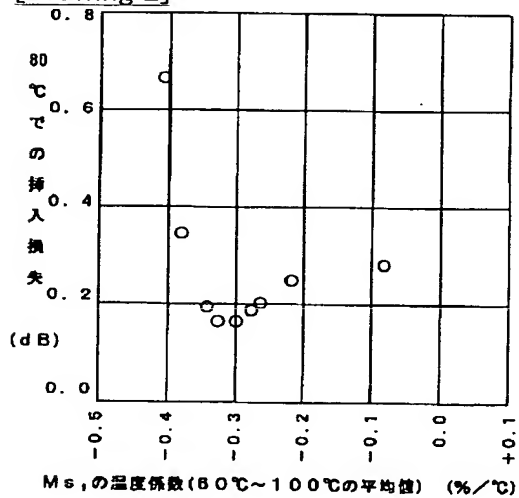2.**** shows the word which can not be translated.
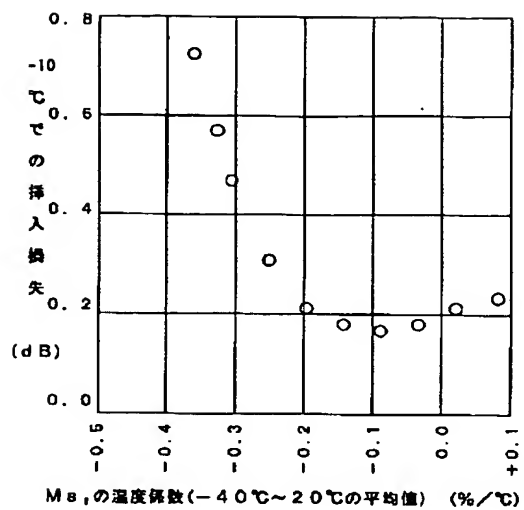3.In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the decomposition perspective diagram view of a **** non-reciprocal circuit element at one example of this invention.
[Drawing 2] It is drawing which explains the property of a **** example to this invention.
[Drawing 3] It is drawing which explains the property of an example besides **** to this invention.
[Drawing 4] this invention — **** — it is drawing explaining the property of another example
[Drawing 5] It is drawing which explains the property of **** and another example to this invention.

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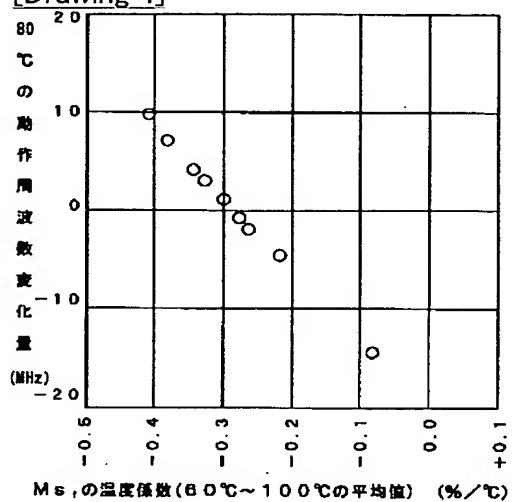3.In the drawings, any words are not translated.

DRAWINGS

[Drawing 1]

金属ケース（上の磁気ヨーク）
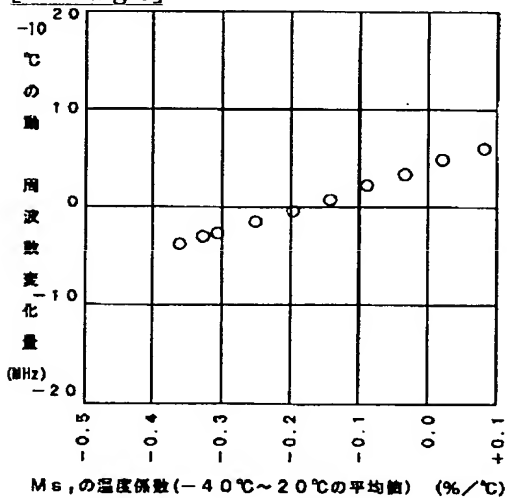
永久磁石

中心導体

所定の温度係数の
マイクロ波フェライト

コンデンサ

抵抗素子

アース板

金属ケース（下の磁気ヨーク）

絶縁基板

[Drawing 2]

Ms₁の温度係数（60℃～100℃の平均値）（％／℃）

[Drawing 3]

-10℃での挿入損失 (dB)

Ms,の温度係数(-40℃~20℃の平均値) (%/℃)

[Drawing 4]

80℃での動作周波数変化量 (MHz)

Ms,の温度係数(60℃~100℃の平均値) (%/℃)

[Drawing 5]

-10℃での動作周波数変化量 (MHz)

Ms,の温度係数(-40℃~20℃の平均値) (%/℃)

[Translation done.]

(51)Int.Cl.⁶		識別記号		F I		
H 0 1 F	1/34			H 0 1 F	1/34	J
H 0 1 P	1/36			H 0 1 P	1/36	A
	1/383				1/383	A
H 0 3 L	1/02			H 0 3 L	1/02	

審査請求 未請求 請求項の数5 ＯＬ （全 8 頁）

(54)【発明の名称】 非可逆回路素子

(57)【要約】
【課題】 挿入損失および動作周波数が広い温度領域に
亘って優れた非可逆回路素子、その素子用のマイクロ波
フェライト材料、およびその素子の温度補償方法を提供
する。
【解決手段】 高磁界動作型の非可逆回路素子の、Ｓr
フェライト磁石の飽和磁化（Ｍsm）とＧd－Ｃa－Ｖ
－Ｉn置換型ＹＩＧの飽和磁化（Ｍsf）の比（Ｍsm／
Ｍsf）が、低温側と高温側のいずれにおいても、常温
時よりも大きな特定の値となるように構成した。その材
料。その温度補償方法。

金属ケース（上の磁気ヨーク）
永久磁石
中心導体
所定の温度係数の
マイクロ波フェライト
コンデンサ
抵抗素子
アース板
金属ケース（下の磁気ヨーク）
絶縁基板
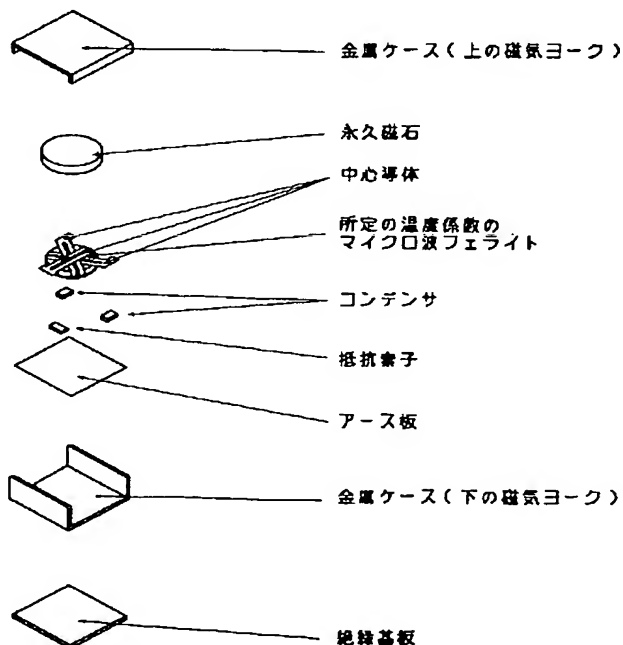
【特許請求の範囲】

【請求項１】　強磁性共鳴磁界より高い磁界で動作する非可逆回路素子であって、永久磁石の飽和磁化（Msm）とマイクロ波フェライトの飽和磁化（Msf）の比（Msm／Msf）の値が、低温側と高温側のいずれにおいても、常温時よりも大であることを特徴とする非可逆回路素子。

【請求項２】　永久磁石と、磁気ヨークである主成分が鉄の金属ケースと、該永久磁石の磁束を印加されるマイクロ波フェライトと、該マイクロ波フェライト近傍に配置された複数本のストリップラインと、該ストリップラインに電気的に接続する容量要素とを有する非可逆回路素子であって、前記マイクロ波フェライトの飽和磁化（Msf）の温度係数は、－４０℃～２０℃の温度領域における平均値が０％／℃～α％／℃（ただしαは前記永久磁石の飽和磁化（Msm）の－４０℃～２０℃における温度係数）であり、かつ６０℃～１００℃の温度領域における平均値が（１．５×β）％／℃～（１．９×β）％／℃（ただしβは前記永久磁石の飽和磁化（Msm）の６０℃～１００℃における温度係数）であることを特徴とする非可逆回路素子。

【請求項３】　永久磁石と、磁気ヨークである主成分が鉄の金属ケースと、該永久磁石の磁束を印加されるガーネット型フェライトと、該ガーネット型フェライト近傍に配置された複数本のストリップラインと、該ストリップラインに電気的に接続する容量要素とを有する非可逆回路素子であって、前記永久磁石はフェライト磁石であり、かつ前記ガーネット型フェライトの飽和磁化（Msf）の温度係数は－４０℃～２０℃の温度領域における平均値が０％／℃～－０．１８％／℃であり、かつ６０℃～１００℃の温度領域における平均値が－０．２７％／℃～－０．３４％／℃であることを特徴とする非可逆回路素子。

【請求項４】　組成式Gd$_z$Y$_{3-2x-z}$ Ca$_{2x}$Fe$_{2-y}$In$_y$Fe$_{3-x}$V$_x$O$_{12}$で表され、かつ前記組成式において、０＜x≦０．７、０．２５＜y≦０．４、０．３５≦z≦１．６を満足する組成からなることを特徴とする磁性材料。

【請求項５】　強磁性共鳴磁界より高い磁界で動作する非可逆回路素子の温度特性を補償する方法であって、永久磁石の飽和磁化（Msm）とマイクロ波フェライトの飽和磁化（Msf）の比（Msm／Msf）の値が、低温側と高温側のいずれにおいても、常温時よりも大となるようにすることを特徴とする非可逆回路素子の温度特性を補償する方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、１００MHz以上２０GHz以下で用いられる集中定数型の非可逆回路素子すなわちアイソレータやサーキュレータに関するもの

であり、また、温度特性に優れた非可逆回路素子を得るための磁性材料に関するものであり、あるいは、挿入損失や中心周波数の温度特性に優れた、非可逆回路素子を得るための温度補償の方法に関するものである。

【０００２】

【従来の技術】１００MHzから２０GHzの周波数帯を利用した高周波機器には、アイソレータやサーキュレータといった非可逆回路素子を用いることが多い。この素子は特定の周波数で順方向の高周波を低損失で通過せしめ、逆方向の高周波を阻止せしめる機能を有する。

【０００３】通常の集中定数型非可逆回路素子は、永久磁石と、その磁気ヨークである主成分が鉄の金属ケースと、永久磁石の磁束を印加されるマイクロ波フェライトと、このマイクロ波フェライト近傍に配置された複数本のストリップラインや中心導体と、該ストリップラインに電気的に接続する容量要素（例えばチップコンデンサのような容量素子）とを有する構造である。また通常上記マイクロ波フェライトと上記磁石とは積み重なるように配置されている。

【０００４】なお、非可逆回路素子の１つである３端子サーキュレータの１端子を抵抗素子で終端すればアイソレータとなるものであり、技術的にも形態上もアイソレータとサーキュレータは類似している。

【０００５】かかる非可逆回路素子に要求される最も重要な特性の１つに、当該素子を順方向に通過せしめる高周波の通過時の損失、すなわち挿入損失がある。言うまでもなく挿入損失は小さいほど良い。さらに上記非可逆回路素子が広い温度範囲で優れた性能を維持するためには、挿入損失の温度特性も優れている必要がある。

【０００６】一方、非可逆回路素子に要求される最も重要な特性の他の１つに、周波数特性がある。非可逆回路素子は強磁性共鳴を利用するものであり、通常アバブレゾナンス（avobe　resonanse；マイクロ波フェライトの'μ$^+$'が最大となる直流磁界よりも高磁界側で共鳴させる設計方法）の考え方で設計される。

【０００７】周波数は、当該非可逆回路素子の使用周波数となるように設定される。すなわち、マイクロ波フェライトの飽和磁化（以下、Msfと記述する）の大きさと永久磁石の飽和磁化（以下、Msmと記述する）の大きさとそれらの比率で近似的に決定する周波数が使用周波数となるように設定される。

【０００８】非可逆回路素子が広い温度範囲で優れた性能を維持するためには、環境温度が変化しても、動作周波数があまり変動しないように対策することが重要である。

【０００９】かかる観点から、従来の非可逆回路素子の温度補償には、大別して２種類の対策・対処の方法があった。すなわち第１の方法はMsfとMsmの温度係数が何れも小さくなるようにすることである。

【００１０】たとえば、Msfを小さくするためにはG

ｄ置換型ＹＩＧ系のマイクロ波フェライトを採用し、そのＭｓｆの温度に対する変化が少ない組成の材料を選択すると同時に、Ｍｓｍの変化を少なくするためにはキュリー温度の高い金属系の永久磁石、例えば希土類磁石を採用し、さらに整磁鋼を組み合わせて直流磁気回路の磁気抵抗を調整し、より正確な温度補償を行うという方法である。

【００１１】このような方法による対策は例えば特開昭５０年第３１４００号公報や特開昭５７年第４２５４４号公報に示されている。この方法による場合は当然高価な永久磁石や高価な整磁鋼を用いることになる。

【００１２】そこでより安価な永久磁石としてフェライト磁石を用いることができないかと考えたのが第２の方法である。良く知られているようにフェライト磁石は金属系磁石よりもキュリー温度が低いため、Ｍｓｍの温度係数は必ずしも小さいとは言えない。しかしＭｓｆの温度係数とＭｓｍの温度係数が同程度の大きさであれば環境温度が変化しても動作周波数があまり変動しないようにすることができるものとされてきた。

【００１３】従って、Ｍｓｆの温度係数とＭｓｍの温度係数が同程度の大きさとなるようにマイクロ波フェライトとフェライト磁石の材料を選択して組み合わせることが行われていた。これは言い換えれば、マイクロ波フェライトの飽和磁化（Ｍｓｆ）の大きさと永久磁石の発生磁場の強さとの比率が常に一定であるようにしたものである。

【００１４】しかるに上記第２の方法で充分に温度補償したはずの非可逆回路素子であっても、その素子の挿入損失や中心周波数の温度特性を見ると常温域以外では不充分な値となりがちであった。

【００１５】すなわち環境温度の変化に対して常に挿入損失が少なく、かつ動作周波数の温度安定性に優れた非可逆回路素子を提供することは、容易でなかった。

【００１６】
【発明が解決しようとする課題】そこで本発明が解決しようとする課題は、以下に列挙する課題の少なくとも一つである。

（１）挿入損失が広い温度領域に亘って優れた非可逆回路素子の提供

（２）動作周波数が広い温度領域に亘って安定な非可逆回路素子の提供

（３）広い温度領域に亘って挿入損失が優れ、かつ広い温度領域に亘って動作周波数が安定な非可逆回路素子の提供

（４）安価で高信頼性の、非可逆回路素子の提供

（５）上記課題の少なくともいずれか１つを容易に解決するような磁性材料の提供。

（６）上記課題の少なくともいずれか１つを容易に解決するような温度特性の補償方法の提供。

【００１７】

【課題を解決するための手段】上述の課題を解決するため鋭意研究の結果、本発明者らは、著しく構成を改善した非可逆回路素子、または、かかる非可逆回路素子を得るための磁性材料、あるいは、かかる非可逆回路素子の温度特性を補償する新しい方法に想到したものである。

【００１８】すなわち第１の発明は、強磁性共鳴磁界より高い磁界で動作する非可逆回路素子であって、永久磁石の飽和磁化（Ｍｓｍ）とマイクロ波フェライトの飽和磁化（Ｍｓｆ）の比（Ｍｓｍ／Ｍｓｆ）の値が、低温側と高温側のいずれにおいても、常温時よりも大となるように構成した非可逆回路素子である。

【００１９】本発明の最大の特徴は、従来一定とするのが最善と考えられていたＭｓｍ／Ｍｓｆの値を、低温側のみならず高温側においても、常温での値よりも大きくしたところにある。常温付近のＭｓｍ／Ｍｓｆの値のみを小さくしても結果的には同じことである。

【００２０】このような構成とすることで、広い温度範囲で低損失かつ動作周波数変化の少ないの非可逆回路素子が得られる。すなわち、当該非可逆回路素子の保証規格の飛躍的な向上に繋がるものであるから、その寄与するところは極めて大である。

【００２１】なお、言うまでもないが、部品として完成された非可逆回路素子は一体のものであるから、低温側、高温側、常温付近の３種の温度帯域でそれぞれに適した別々の部品構成をとることはできない。

【００２２】発明者らの検討結果によっても第１の発明のような構成が有効である理由については必ずしも理論的に明快ではないが、以下のような事実が複雑に関与しているものと考えられる。

【００２３】Ｆｅ製磁気ヨークの透磁率の温度特性や熱膨張率によって、磁気回路のパーミアンスが変化すること。一般にテンソル透磁率の、右回りの円偏波に対する透磁率の損失を表す虚数部（通常 $\mu+"$ と記述される）の大きさは、印加磁界の強さが強磁性共鳴を起こす磁界から離れれば離れるほどこれが小さくなること。永久磁石中に漏洩あるいは伝搬するマイクロ波の永久磁石中での損失が環境温度によって変化すること。

【００２４】この発明において、常温とは２０℃近傍の温度、低温側とはおよそ－４０℃以上１０℃以下の温度、高温側とはおよそ４０℃以上１００℃以下の温度である。

【００２５】本願第２の発明は上述の第１の発明の内容をさらに具体的な構成としたものである。すなわち第２の発明は、永久磁石と、磁気ヨークである主成分が鉄の金属ケースと、該永久磁石の磁束を印加されるマイクロ波フェライトと、該マイクロ波フェライト近傍に配置された複数本のストリップラインと、該ストリップラインに電気的に接続する容量要素とを有する非可逆回路素子であって、前記マイクロ波フェライトの飽和磁化（Ｍｓｆ）の温度係数は、－４０℃～２０℃の温度領域におけ

る平均値が０％／℃～α％／℃（ただしαは前記永久磁
石の飽和磁化（Ｍｓₘ）の－４０℃～２０℃における温
度係数）であり、かつ６０℃～１００℃の温度領域にお
ける平均値が（１．５×β）％／℃～（１．９×β）％
／℃（ただしβは前記永久磁石の飽和磁化（Ｍｓₘ）の
６０℃～１００℃における温度係数）であるように構成
した非可逆回路素子である。

【００２６】この発明において、冒頭の「永久磁石と～
非可逆回路素子であって」の部分は従来の集中定数型非
可逆回路素子の一般的な構成である。従ってこの部分は
類似の他の構成であってもよい。ストリップラインは中
心導体であって、３端子サーキュレータや３端子アイソ
レータの場合は３本からなる。

【００２７】容量要素は要するにコンデンサであるが、
最近のものはチップ型や、セラミック基板兼用のものが
多い。その機能は、通常、インピーダンス整合の機能
と、マイクロ波フィルターとしての機能とを併せ持つ。

【００２８】また、飽和磁化の温度係数は、－４０℃～
２０℃の領域における平均値は、
　　（（Ｍｓ₂₀－Ｍｓ₋₄₀）／Ｍｓ₂₀／６０）×１００
で与えられ、同様に、６０℃～１００℃の領域における
平均値は、
　　（（Ｍｓ₁₀₀－Ｍｓ₆₀）／Ｍｓ₂₀／４０）×１００
で与えられる（単位は％／℃である。Ｍｓの右下付数字
は何れも温度を示し、例えばＭｓ₋₄₀は－４０℃におけ
る飽和磁化を示す。式中の６０や４０は、当該温度領域
の温度幅（単位℃）。）ものである。これらの飽和磁化
の値や飽和磁化の温度特性は、振動試料型磁力計（ＶＳ
Ｍ）で容易に正確に測定できる。

【００２９】この発明を別の観点から表現すると、永久
磁石とマイクロ波フェライトのそれぞれのＭｓｆの温度
特性をそれらの２０℃での値でそれぞれ規格化した場合
に、これを１つの図に表せば、それらの温度特性線は常
温付近で互いに接し、かつ、マイクロ波フェライトの温
度特性線が永久磁石のそれよりも内側にあるような２つ
の曲線の関係になることを意味する。

【００３０】上記第２の発明の永久磁石をフェライト磁
石とし、マイクロ波フェライトをガーネット型フェライ
トとした場合について、温度特性の具体的な傾斜を示す
と、本願第３の発明となる。

【００３１】すなわち本願第３の発明は、永久磁石と、
磁気ヨークである主成分が鉄の金属ケースと、該永久磁
石の磁束が印加されるガーネット型フェライトと、該ガ
ーネット型フェライト近傍に配置された複数本の中心導
体と、該中心導体に電気的に接続する容量素子とを有す
る非可逆回路素子であって、前記永久磁石はフェライト
磁石であり、かつ前記ガーネット型フェライトの飽和磁
化（Ｍｓｆ）の温度係数は－４０℃～２０℃の温度領域
における平均値が０％／℃～－０．１８％／℃であり、
かつ６０℃～１００℃の温度領域における平均値が－

０．２７％／℃～－０．３４％／℃であるように構成し
た非可逆回路素子である。

【００３２】この発明において、フェライト磁石はＳｒ
フェライトであればなお良い。フェライト磁石は金属磁
石に較べて比抵抗が大きく、高周波帯域での損失を少な
くすることに有効である。さらにこれがＳｒフェライト
磁石であればＢａフェライトに較べて、Ｍｓₘの温度特
性の直線性が優れ温度係数は約－０．１８％／℃である
と共に広い温度範囲で使用可能である。

【００３３】また、ガーネット型フェライトはＧｄ－Ｃ
ａ－Ｖ－Ｉｎ置換型ＹＩＧであればなお良い。ガーネッ
トの損失に関係する△Ｈ（共鳴吸収半値幅）が小さいこ
とに加えて、本項に規定する温度係数の材料が容易に作
成可能であり、かつ、常温のＭｓｆの値を種々実現可
能、すなわち動作周波数の設定範囲が広くなるので応用
範囲が広がるからである。

【００３４】ただし、Ｇｄ置換型ガーネットでも本項に
規定する温度係数を実現することは、少々常温のＭｓｆ
の値に制約があるものの十分に可能である。他系統のガ
ーネットであってもよいことは言うまでもない。

【００３５】かかる知見を基に発明したものの１つが、
本願第４の発明のＧｄ－Ｃａ－Ｖ－Ｉｎ置換型ＹＩＧの
ガーネット型フェライトである。すなわち本願第４の発
明は、組成式ＧｄｚＹ₃₋₂ₓ₋ｚ Ｃａ₂ₓ Ｆｅ₂₋ｙ Ｉｎｙ Ｆｅ₃₋ₓ
Ｖₓ Ｏ₁₂で表され、かつ、０＜ｘ≦０．７、０．２５＜
ｙ≦０．４、０．３５≦ｚ≦２．０を満足する磁性材料
である。

【００３６】この磁性材料を本願第１～３の発明に適用
すれば、挿入損失や動作周波数の温度特性に優れた非可
逆回路素子が得られる。

【００３７】本願第５の発明は、方法に関するものであ
り、技術内容は第１の発明と共通するものである。すな
わち本願第５の発明は、強磁性共鳴磁界より高い磁界で
動作する非可逆回路素子の温度特性を補償する方法であ
って、永久磁石の飽和磁化（Ｍｓₘ）とマイクロ波フェ
ライトの飽和磁化（Ｍｓｆ）の比（Ｍｓₘ／Ｍｓｆ）の値
が、低温側と高温側のいずれにおいても、常温時よりも
大となるようにする非可逆回路素子の温度特性を補償す
る方法である。

【００３８】
【発明の実施の形態】図１は、本発明を説明するため
の、代表的な非可逆回路素子の、この場合はアイソレー
タの分解斜視図である。図１は、視認性を確保するため
に模式的に描いているので各部の縮尺や形状について
は、正確ではない。

【００３９】まず非可逆回路素子の構造の内、従来型の
集中定数型非可逆回路素子と共通する部分についての概
要は、例えば、移動体通信用を例に図１に基づいて説明
すると、以下の通りである。ただし、図１のタイプ以外
の種々のアイソレータやサーキュレータであっても良い

ことは言うまでもない。

【００４０】外部端子電極を有する絶縁基板に鉄製の下の磁気ヨークを固着し、これに銅製のアース板（省略可）をハンダ付けし、その上に中心導体の接地部をハンダ付けし、その上に円板状のマイクロ波フェライトを固着し（例えば樹脂で加熱接着する）、上記中心導体のストリップライン部の１つの端子を、上記マイクロ波フェライトを包むように折り曲げる。続いて上記中心導体の他の１つの端子を同様に折り曲げ、先の端子との間に絶縁フィルム（図示せず。）を挟む。同様の手順を繰り返して残った端子を折り込む。

【００４１】これに、予め用意した、上の磁気ヨークに円板状の永久磁石を固着し（例えば、樹脂で加熱接着する方法でも良い）その永久磁石を直流電磁石で着磁し磁力を調整したものを填め合わせる。

【００４２】また、上記中心導体のストリップライン部からの延出部は、上記絶縁基板に設けられた入出力外部端子に接続せしめる。さらに上記中心導体のストリップライン部からの延出部と上記アース板との間には整合用のチップコンデンサを挿入し接続する。チップコンデンサに代えてセラミックの誘電体基板を用いる方法もある。

【００４３】このようにして作成した非可逆回路素子は上記永久磁石の発生磁力を微調整することによって所望の動作周波数となるように正確に設定する。

【００４４】なお、ここに上記入出力端子が３個であって、その内の１個は抵抗素子を介してアース板に接続するような配置とすれば、残った２個を入力端子、出力端子とするアイソレータが作成できる。

【００４５】次に本願発明の実施の形態についてその概要を説明する。上述の永久磁石と、マイクロ波フェライトの飽和磁化（Ｍsm）、（Ｍsf）の温度特性をそれぞれ測定し、それらの所定温度領域の温度係数を求めて比較し、所定の範囲にあるものを選抜し、その選抜の結果選ばれた材料を用いて非可逆回路素子とすればよい。

【００４６】あるいは、特には永久磁石としてフェライト磁石を、さらに望ましくはＳrフェライト磁石を採用し、マイクロ波フェライトとしては、特にはガーネット型フェライト、さらに望ましくは所定の組成を有するガーネット型フェライト材料を採用し、これらを用いて非可逆回路素子とすればよい。

【００４７】以下に本願発明の詳細を実施例に基づいて説明する。

【実施例】（実施例１）実施例１は、永久磁石として異方性Ｓrフェライト磁石、マイクロ波フェライトとして各種Ｇd－Ｃa－Ｖ－Ｉn置換型ＹＩＧの飽和磁化のそれぞれの温度係数と、それらを用いて作成した非可逆回路素子の挿入損失や動作周波数の温度特性との関係を明らかにするために行った実験に関するものである。

【００４８】まず市販の異方性Ｓrフェライト磁石円板

を準備した。その飽和磁化（Ｍsm）の温度特性はＶＳＭを用いて測定した。さらにマイクロ波フェライトとしてはＧd－Ｃa－Ｖ－Ｉn置換型ＹＩＧの各種置換盤の材料を作成し、円板状に加工したものを準備した。これらの飽和磁化（Ｍsf）の温度特性も、ＶＳＭを用いて測定した。

【００４９】上記Ｇd－Ｃa－Ｖ－Ｉn置換型ＹＩＧの作成手順は以下の通りである。いずれも市販品で試薬特級のＧd₂O₃、ＣaＣO₃、Ｖ₂O₅、Ｉn₂O₃、Ｙ₂O₃、およびＦe₂O₃の粉末を用意した。

【００５０】さらに、組成式 $Gd_z Y_{3-2x-z} Ca_{2x} Fe_{2-y} In_y Fe_{3-x} V_x O_{12}$ の x、y、z をそれぞれ、x は０～０．７、y は０～０．６、z は０～２の範囲内で各種変化させた組成となるように、上記に準備した粉末を秤量し、ボールミルを用いてエチルアルコール中で２４時間混合したのち、乾燥、解砕して混合粉を得た。

【００５１】これらの混合粉は、セラミック製のケース中で、１０００℃２時間、大気雰囲気中にて仮焼して仮焼粉とした。この仮焼粉は解砕後ボールミルを用いてエチルアルコール中で２４時間粉砕した。これを乾燥後、濃度１０％のポリビニールアルコール水溶液を固形分にして１重量％相当量を添加し、造粒、整粒して原料顆粒とした。

【００５２】上記作成した原料顆粒を金型に充填し、油圧プレスによる乾式加圧成形法により、約１００ＭＰaで円板状の成形体を得た。これらの成形体は、１２７０℃酸素雰囲気中で３時間焼成して焼成体とした。これらの焼成体は外周および上下面に研磨加工を施して非可逆回路素子用のマイクロ波フェライトとした。

【００５３】なお、これらの焼成体は別途Ｘ線回折法で確認したところ、ほぼガーネット単相であった。その他の基本特性として、常温でのＭsfは５０～１３０mTであり、また強磁性共鳴半値幅△Ｈは５６０～６，９００Ａ／m（ただし大半の試料は１，８００～２，１００Ａ／mの範囲内）のものが各種得られた。

【００５４】以上に準備した永久磁石と各種マイクロ波フェライトとを組み合わせ、通常の要領で非可逆回路素子を作成し、常温２０℃にて、挿入損失が最小となりかつ動作周波数がおよそ３００ＭＨzとなるように調整したものについて、挿入損失の温度特性を測定した。測定器および測定系は、恒温槽とネットワークアナライザと、正確に調整したケーブルと接続端子からなる自作治具によるものである。

【００５５】なお、非可逆回路素子の挿入損失および動作周波数の測定点は－１０℃、２０℃、８０℃とした。－１０℃は－４０℃～２０℃の中間点の温度、２０℃は常温、８０℃は６０℃～１００℃の中間点の温度である。

【００５６】また、周波数の３００ＭＨzは、用途からすると最も低い周波数帯に属するが、判断を正確にする

ためには低周波の方が有利だからである。別途約２ＧＨ
ｚで確認して、その判断の正当性が確認できた。すなわ
ち少なくとも２ＧＨｚまでは本発明の効果が変わらない
ことを確認した。

【００５７】以上のようにして測定した結果を図２に示
す。図２は各種マイクロ波フェライトの飽和磁化（Ｍｓ
ｆ）の温度係数（ただし６０℃～１００℃の平均値）
と、これらのマイクロ波フェライトを用いて作成したそ
れぞれのアイソレータの８０℃での挿入損失の値であ
り、この時用いた永久磁石はいずれもＳｒフェライト
（温度係数の６０℃～１００℃の平均値は、０．１９％
／℃）である。

【００５８】図２によれば、挿入損失の値はマイクロ波
フェライトの飽和磁化（Ｍｓｆ）の温度係数（ただし６
０℃～１００℃の平均値）が－０．２７～－０．３４の
範囲内に有れば極めて小さく、すなわち０．２ｄＢ以下
となっている。

【００５９】さらに、注目すべきことは、上記温度係数
が０％／℃付近の場合および上記温度係数が－０．１９
％／℃付近の場合は、何れの場合も挿入損失が０．２５
ｄＢ以上であり、悪い値ではないものの最善とは言えな
いということである。

【００６０】同様にして測定した低温側での検討結果を
図３に示す。図３は各種マイクロ波フェライトの飽和磁
化（Ｍｓｆ）の温度係数（ただし－４０℃～２０℃の平
均値）と、これらのマイクロ波フェライトを用いて作成
したそれぞれのアイソレータの－１０℃での挿入損失の
値であり、この時用いた永久磁石Ｓｒフェライトの温度
係数の－４０℃～２０℃での平均値は、０．１８％／
℃）である。

【００６１】図３によれば、－１０℃における挿入損失
の値はマイクロ波フェライトの飽和磁化（Ｍｓｆ）の温
度係数（ただし－４０℃～２０℃の平均値）が０～－
０．１８％／℃の範囲内に有れば極めて小さく、すなわ
ち０．２ｄＢ以下となっている。

【００６２】ここでさらに注目すべきことは、上記温度
係数が先の温度係数（６０～１００℃）での最適点と異
なる位置に最適点を有することである。０％／℃以上の
場合および上記温度係数が－０．１９％／℃以下の場合
は、何れの場合も挿入損失が０．２ｄＢ以上であり、悪
い値ではないものの最善とは言えない。

【００６３】図４、図５は図２、図３における検討と同
じ条件下で、挿入損失の所を動作周波数の変化量とした
評価結果である。負号は動作周波数が低周波化したこと
を示す。図４によれば、２０℃を基準とした８０℃にお
ける動作周波数の変化量が５ＭＨｚ以内となるようなＭ
ｓｆの温度係数（６０℃～１００℃の平均値）は、およそ
－０．２３～－０．３６％／℃である。

【００６４】また図５によれば、２０℃を基準とした－
１０℃における動作周波数の変化量が５ＭＨｚ以内とな

るようなＭｓｆの温度係数（－４０℃～２０℃の平均値）
は、およそ－０．４～＋０．０２％／℃である。

【００６５】図４、５に示した事実から注目すべき点
は、永久磁石の温度係数とマイクロ波フェライトの温度
係数とを単純に一致させても理想的な温度補償は困難で
あること、特に低温側では従来定説であった点よりも、
フェライトの飽和磁化がより少なくなるように補償すべ
きであることである。

【００６６】さらに図２～図５を総合的に判断すると、
挿入損失が少なくかつ動作周波数の変化量が少ない非可
逆回路素子を得るためのマイクロ波フェライトの温度係
数は、高温側（６０～１００℃）で－０．２７～－０．
３４％／℃、低温側（－４０～２０℃）で０～０．１８
％／℃である。

【００６７】（実施例２）次に、実施例１で用いたガー
ネット型マイクロ波フェライトであるＧｄ－Ｃａ－Ｖ－
Ｉｎ置換型ＹＩＧの各元素成分の原子比であるｘ、ｙ、
ｚの各値と前述温度係数との関係について詳細に調べ
た。その結果を以下に示す。

【００６８】Ｇｄ－Ｃａ－Ｖ－Ｉｎ置換型ＹＩＧの飽和
磁化（Ｍｓｆ）の温度係数を－４０℃～２０℃の温度領
域における平均値が０％／℃～－０．１８％／℃であ
り、かつ６０℃～１００℃の温度領域における平均値が
－０．２７％／℃～－０．３４％／℃となるようにする
ためには、以下のようにすればよい。

【００６９】すなわち、組成式 $Gd_z Y_{3-2x-z} Ca_{2x} Fe_{2-y} In_y Fe_{3-x} V_x O_{12}$ で、$0 < x \leq 0.7$、$0.25 < y \leq 0.4$、$0.35 \leq z \leq 1.6$ を満足する組
成とすればよい。

【００７０】ただし、$x > 0.7$ かつ $z < 0.35$ であ
っても温度係数に限って言えば上述の条件を満たすが、
この場合は過剰に焼結が進み低損失の材料とならない。
また $y \leq 0.25$ では、結晶粒が微細となるため、低損
失とならない。$y \geq 0.4$ では低温側の温度係数が負と
なり適当でないし、過剰に焼結が進み損失を悪化させ
る。$z < 0.35$ では低温側の温度係数が過大、$z >$
1.6 では高温側の温度係数が過大となり、望ましくな
い。

【００７１】たとえば、組成式 $Gd_{0.8} Y_{1.2} Ca_1 Fe_{1.7} In_{0.3} Fe_{2.5} V_{0.5} O_{12}$ すなわち $x = 0.5$、$y =$
0.3、$z = 0.8$ としたときの緒量は、以下の通りと
なった。マイクロ波フェライトについては２０℃での飽
和磁化（Ｍｓｆ）は７５ｍＴ、強磁性共鳴吸収半値幅
（ΔＨ）は１２４０Ａ／ｍであった。その温度係数は、
－４０℃～２０℃で－０．１５％／℃、２０℃近傍で－
０．１７％／℃、６０℃～１００℃で－０．２９％／℃
であった。

【００７２】このマイクロ波フェライトを用いて作成し
た非可逆回路素子については、挿入損失は－１０℃で
０．１９ｄＢ、２０℃で０．１７ｄＢ、８０℃で０．１

8dBであり、動作周波数は－10℃で330MHz、20℃で329MHz、80℃で330MHzであった。

【0073】（実施例3）実施例1のSrフェライト磁石の所を異方性Baフェライト磁石、等方性サマリウムーコバルト系磁石、等方性Nd－Fe－B系磁石のいずれも市販品に替えて実施例1と同様の検討を行った。ただし、等方性サマリウムーコバルト系磁石、等方性Nd－Fe－B系磁石については動作周波数調整のためフェライト磁石よりも薄い円板状とした。

【0074】各磁石の飽和磁化（Msm）の温度特性を、VSMを用いて測定したところ、何れの材料も温度による温度係数の変化は少なく、異方性Baフェライト磁石は－0.19%／℃、等方性サマリウムーコバルト系磁石は－0.04%／℃、等方性Nd－Fe－B系磁石は－0.12%／℃であった。

【0075】実施例1と同様にしてマイクロ波フェライトの最適な温度係数を求めたところ、異方性Baフェライト磁石については実施例1とほぼ同一の結果を得た。等方性サマリウムーコバルト系磁石については、低温側（－40～20℃）では0～－0.4%／℃、高温側（60～100℃）では－0.6～－0.8%／℃が最適であった。等方性Nd－Fe－B系磁石については、低温側では0～－0.12%／℃、高温側では－0.17～－0.23%／℃が最適であった。

【0076】以上の結果によれば、非可逆回路素子用マイクロ波フェライトの温度係数の最適範囲は、永久磁石の温度係数との比率で決まる。－40℃～20℃温度係数は0～α%／℃、60℃～100℃温度係数は（1.5×β）%／℃～（1.9×β）%／℃が、最適（ただしα、βは永久磁石の飽和磁化（Msm）の同温度域における温度係数）であることがわかった。

【0077】（実施例4）実施例3で判明した最適温度係数の関係については、実施例3のGd－Ca－V－I

n置換型YIGの所を、Gd置換型YIG、Al置換Coドープ型Ni系スピネルフェライトのいずれも各種置換量の市販品に替えた場合についても実施例3と同様に確認した。その結果、上記と同結論を得た。

【0078】さらに、動作周波数の設定を変えるため、マイクロ波フェライトへの印加磁場を強め、マイクロ波フェライトの飽和磁化（Msf）がより大きい組成の材料を選んで試作したところ、少なくとも2GHzまでは上記結論に変化がないことを確認した。

【0079】なお、この試作にあたり非可逆回路素子の構造は、次の点で図1に示す構造とは異なるものとした。下の磁気ヨークは略平板とし、上の磁気ヨークは孔部を有する箱形とし、孔部にピン端子を設けて入出力端子とした。絶縁基板は省略した。コンデンサの容量、抵抗素子の耐電力性を変更した。

【0080】

【発明の効果】以上詳細に説明したように、本発明によれば、低損失にして損失や動作周波数の温度特性に優れた非可逆回路素子を提供することが可能となった。あるいは該非可逆回路素子用のマイクロ波フェライトの提供が可能となった。あるいは、理想的にして新規な温度補償方法を提供することができた。
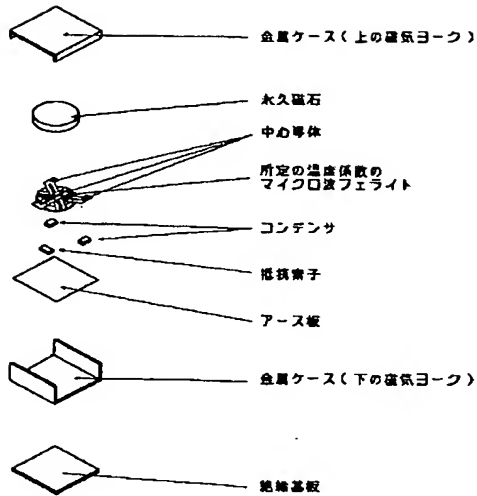
【図面の簡単な説明】

【図1】本発明の一実施例に関る非可逆回路素子の分解斜視図図である。
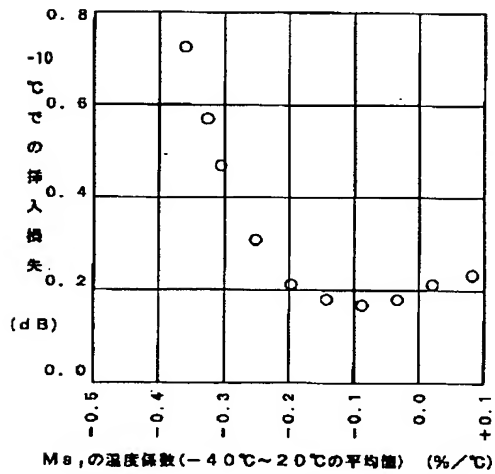
【図2】本発明に関る実施例の特性を説明する図である。

【図3】本発明に関る他の実施例の特性を説明する図である。

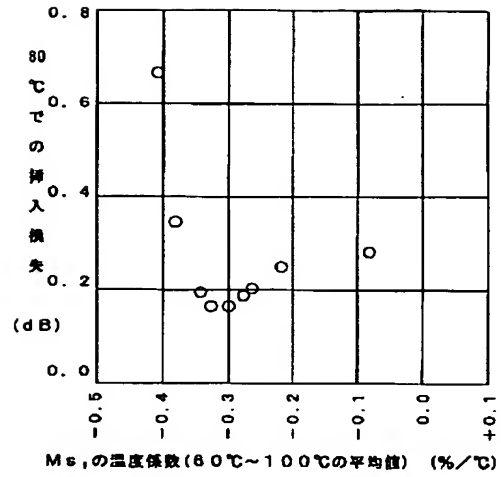【図4】本発明に関る別の実施例の特性を説明する図である。

【図5】本発明に関るまた別の実施例の特性を説明する図である。

【図1】

金属ケース（上の磁気ヨーク）
永久磁石
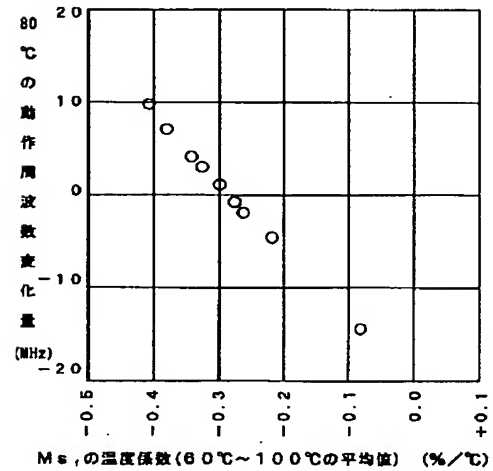中心導体
所定の温度係数の
マイクロ波フェライト
コンデンサ
抵抗素子
アース板
金属ケース（下の磁気ヨーク）
絶縁基板

【図2】

80℃での挿入損失 (dB)

Msの温度係数（60℃～100℃の平均値）（%/℃）

【図3】

-10℃での挿入損失 (dB)

Msの温度係数（-40℃～20℃の平均値）（%/℃）

【図4】

80℃の動作周波数変化量 (MHz)

Msの温度係数（60℃～100℃の平均値）（%/℃）

【図5】

-10℃の動作周波数変化量 (MHz)

Msの温度係数（-40℃～20℃の平均値）（%/℃）